CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-244

SIMI-SANTA ROSA FAULT ZONE

in the Moorpark, Newbury Park, Simi Valley East[1], Simi Valley West[2], and Thousand Oaks Quadrangles
Ventura County, California

by
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INTRODUCTION

The Simi-Santa Rosa fault zone is a prominent reverse fault system that extends for over 40km (25 miles) across Ventura County, from the Camarillo Hills, east of the Oxnard Plain, eastward to the northeastern end of Simi Valley (Figure 1). The active western end of the fault zone, including the Camarillo and Springville faults, was evaluated in Fault Evaluation Report FER-237 (Treiman, 1997). Pursuant to recommendations made in that report, several fault traces have been included within new Alquist-Priolo Earthquake Fault Zones (California Division of Mines and Geology, 1998a,b). The purpose of this study is to evaluate the remaining portion of the Simi-Santa Rosa fault zone and determine whether individual fault traces are sufficiently active and well defined to be included in a new Alquist-Priolo Earthquake Fault Zone (Hart and Bryant, 1997). When the Simi and Santa Rosa faults were previously evaluated (Smith, 1977), there was insufficient evidence to include the faults within an Earthquake Fault Zone. However, recent studies in the Tierra Rejada and Simi valleys have found evidence of Holocene faulting. The study area for this evaluation includes the northern portion of the Newbury Park and Thousand Oaks 7.5' quadrangles and the southern portion of the Moorpark, Simi Valley East and Simi Valley West 7.5' quadrangles (Figure 1). Faults in the eastern half of the Simi Valley East quadrangle are not included in the current evaluation or zoning recommendations.

A largely unmapped, but closely related, fault and structural zone, the "Santa Rosa Valley fault" is also being evaluated for zoning under the Alquist-Priolo Earthquake Fault Zoning Act (APEFZA). This fault has already been zoned to the west, in the Camarillo quadrangle (Treiman, 1997; CDMG, 1998a).

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[1] previously called the Santa Susana quadrangle

[2] previously called the Simi quadrangle

SIMI-SANTA ROSA FAULT ZONE

Summary of Available Data (Figures 2a,b,c)

Unnamed elements of the Simi-Santa Rosa fault zone were first mapped, east of Chivo Canyon in Simi Valley and in the eastern Santa Rosa Valley, by Kew (1919, 1924). The fault zone was depicted more completely and called the Simi fault by Bailey (1951) and the Simi Valley fault by Bailey & Jahns (1954, plate 4). The State Water Resources Board referred to the Simi-Santa Rosa fault system, which consists of several branches (1956, p.B-32). They showed the Simi fault from Tierra Rejada Valley eastward, with the western segment labeled the Santa Rosa fault zone (State Water Resources Board, 1956, Plate B-1C). These earlier studies and compilations were at scales of 1:48,000 or smaller.

Later compilations, at 1:48,000, were by Weber and others (1973 & 1976). In addition to being compilations, these studies included some original mapping and aerial photo interpretation. In the 1973 compilation, the western fault is called the Santa Rosa fault and the eastern one, the Simi fault. In the 1976 compilation the entire zone is labeled Simi fault zone. Faults shown by Weber and others (1973 & 1976) that are not from other sources are included on Figures 2a,b,c.

Larger scale mapping was done for thesis work by Pasta (1958), Jakes (1979) and Hanson (1981). These three students did not refer to the Santa Rosa fault on their maps (1:24,000), instead using "Simi fault" for the principal trace. Dibblee (1992a,b&c), and Dibblee and Ehrenspeck (1990) also refer to most of the fault as the Simi fault, but call the southern trace on the Newbury Park quadrangle the Santa Rosa fault. Another compilation at 1:24,000, from Tierra Rejada Valley eastward, was by Squires (1983).

Hanson and Jakes focused on the interpretation of subsurface data from oil fields and largely compiled their surface mapping; both recognized that the fault was a Tertiary age structure with continuing displacement in the Quaternary. Vertical separation of the Paleogene strata diminishes eastward, from 1097m (in the eastern Las Posas Hills), to 1615m (east of the Tierra Rejada Valley), to 1036m (in the western Simi Valley), to only 15m (at the eastern end of Simi Valley) (Jakes, 1979; Hanson, 1981). Hanson (1981, 1982) concluded that most displacement was pre-middle Miocene, based on only 440m separation of middle Miocene strata where the older Sespe Formation had 1615m separation. Exploration for petroleum has defined the fault in the sub-surface, with dips of 63°-77°N (Jakes, 1979; Hanson, 1981).

Hanson (1981, 1982, 1983) cited earlier studies which proposed large lateral offset along the Simi fault (on the order of tens of kilometers, both right- and left-lateral), and then proceeded to argue that such large offsets were unlikely. He based this conclusion on correlation of facies and markers in the Paleocene through Oligocene bedrock units (based on petroleum industry data). However, his data do not restrict lesser offsets of a few kilometers.

As shown on Figures 2a,b & c, the fault strands have been connected in various manners and slightly differing locations by each geologist or geologic compiler. I will use the name "Simi fault" for the main trace mapped from Tierra Rejada Valley eastward, and, following Jakes, for the continuous main strand which continues to the west within the front of the Las Posas Hills (Jake's northern strand). I will apply the name "Santa Rosa fault", as Dibblee did, to the southern strand of the fault at the western end of the Las Posas Hills and extend this usage eastward to Tierra Rejada Valley, applied to the apparently younger fault at the southern base of the hill mapped by Weber and others (1976). The Simi and Santa Rosa faults were previously evaluated by Smith (1977), who concluded at that time that, although well-defined, there was insufficient evidence to show that the faults were active. For ease of discussion, details of the Simi and Santa Rosa faults will be discussed from west to east, in sections, according to USGS quadrangles (see Figure 1). Site specific studies, referred to in the following summary, are more completely compiled in Table 1.

Camarillo quadrangle *(recap from Treiman, 1997)*

Studies on the Camarillo quadrangle (locality **6**) by Staal, Gardner & Dunne (1988) and by Geolabs (1990b) found no evidence for the Simi or Santa Rosa faults as projected across the Holocene flood plain deposits of Calleguas Creek (Pasta, 1958; Weber and others, 1973 & 1976), and zoning of these faults was not recommended on that quadrangle (Treiman, 1997).

Newbury Park and Moorpark quadrangles (Figure 2a)

Two to three main fault strands, and several minor strands, have been mapped by various workers across the width of these two quadrangles. The two principle strands in the western third of the quadrangle (Simi fault and Santa Rosa fault herein) were called the northern and southern strands of the Simi fault by Jakes (1979). Pasta (1958) mapped the northern strand as being continuous with his "Kew Quarry fault", whereas Jakes (1979) mapped the latter fault as an independent fault trace. The northern strand (Simi fault) was found to dip 60°-65°N in the near surface, with 150 feet separation of the base of the Saugus Formation, but steepening with depth (Jakes, 1979). The "Kew Quarry fault" of Pasta roughly coincides with the Simi fault of Dibblee (1992c) and Dibblee and Ehrenspeck (1990). Dibblee and Ehrenspeck (1990) refer to the southern trace as the Santa Rosa fault, and do not recognize any continuity with their Simi fault to the east. Geotechnical studies have corroborated portions of the Simi fault (localities **9** & **12**), but not the Santa Rosa fault (Blake, 1991; Blake and Larson, 1991). An additional splay of the Simi fault has been revealed, however, between the two faults (localities **8b**, **10**, **12**, **14**, **17** & **18**). The Simi fault and its splay were found to offset soil and colluvium of uncertain age (localities **8b**, **12** & **18**; see Figure 4). Trenching at locality **8a** suggested that the Simi fault may die out to the west, but the data were not conclusive. The Simi splay appears to merge eastward with the main strand as they enter Santa Rosa Valley.

Most workers generally concur in their mapping of the Simi fault eastward across the remainder of these two quadrangles, north of Santa Rosa Valley, with some slight variations in the less continuous fault strands exposed within the steep, eroded terrain north of the Simi fault. Studies along the Simi fault (localities **19**, **21**, **23**, **24** and **25**) have verified its location and width (as much as 200 feet) but have not provided any information on recency of movement. Weber and others (1976) map an additional lower fault along the main slope break between the Las Posas Hills and Santa Rosa Valley. The Santa Rosa fault has not had any defining studies done yet, but apparent hanging-wall splays of this fault have been found to pond and offset slopewash deposits (locality **20**).

Simi Valley West and Thousand Oaks quadrangles (Figure 2b)

One principal fault strand has been mapped across the Simi Valley West quadrangle (Pasta, 1958; Hanson, 1981; Squires, 1983; McClelland Engineers, 1985; Dibblee, 1992b). This relatively straight section of the Simi fault commonly juxtaposes Oligocene Sespe Formation and Miocene Conejo Volcanics, on the north, against Plio-Pleistocene Saugus Formation and younger deposits on the south. Several northeast-trending splay faults have been mapped north of Tierra Rejada Valley

(Pasta, 1981; Squires, 1983; McClelland Engineers, 1985; Blake and Ploessel, 1991), of which only the more continuous splays have been plotted. In the eastern half of the quadrangle the fault defines the mountain front, but is otherwise concealed by alluvium. Some of the probably widespread upper-block faults have been observed at localities **34a** and **41**.

Consulting studies have better defined the fault (localities **28-31**, **33-37** & **40**), and documented the presence of low-angle thrust faults to the south of the main strand (localities **31** & **36**). Faulted Quaternary deposits were observed at localities **30**, **31**, **32b**, **33**, **34**, **36**, **37**, **40** and **41**. Probable Holocene displacement was indicated at localities **30**, **31** (Figure 5), **36** and **37** (and perhaps locality **40**); locality **37** documented Holocene displacement based on dating of detrital charcoal (see Figure 6). Mullion in the vertical fault plane at this latter locality (plunging 30° to the northeast) suggest left-oblique displacement. A relatively abrupt change in depth to bedrock was observed at localities **37** & **39**. Although most data suggest a north-dipping fault, locality **28** documents a south-dipping fault strand. Another south-dipping fault, at locality **31b**, may be a backthrust to the inferred thrust immediately to the south.

Fossils (*Lituyapecten cf. L. dilleri* (Dall)) collected from the hills immediately north of Arroyo Santa Rosa and west of Tierra Rejada Valley (actually on the Moorpark quadrangle), date these marine rocks as Pliocene [collected by P.Irvine, CDMG, and tentatively identified by L.Groves, Los Angeles County Museum of Natural History). These rocks are overlain by basalt, basalt breccia and inter-volcanic sediments of the Miocene Conejo Volcanics, implying the presence of an intervening fault (not shown), possibly the eastern end of the Santa Rosa fault. Although a through-going fault has not been previously recognized between these exposures, Stone (1965) mapped two short northwest-dipping faults within a basalt flow and conglomerate unit (locality **27**). Recent mapping (Dibblee, 1992b and 1992c) has interpreted the volcanic breccia as a Pleistocene-age landslide deposit derived from the older volcanics, however mapping for residential development (locality **26**) has provided additional evidence that the volcanics are in place, at least to the west of Tierra Rejada Valley.

<u>Simi Valley East quadrangle</u> (formerly Santa Susana quadrangle) (Figure 2c)

The Simi fault presents a very straight trace trending east-northeast across the western half of this quadrangle (Hanson, 1981; Dibblee, 1992a; Squires, 1983). From Marr Ranch eastward the fault splays into several faults that begin to veer eastward and then to the east-southeast. Dibblee (1992a) mapped two splays which he called the North and South branches of the Simi fault. Dibblee (1991) implies a possible continuation eastward as his North branch of the Simi fault projects discontinuously toward the Mission Hills fault. Faults more than 1km east of Marr Ranch have not been evaluated for recency in this FER.

Hanson (1981) depicted a less simple fault interpretation, derived in part from subsurface petroleum exploration. His Simi fault trends easterly across Marr Ranch and dies out across Chivo Canyon. He shows two other faults across Marr Ranch: a south dipping splay of the Simi fault that just reaches Chivo Canyon and, slightly farther north, the steeply south-dipping Marr fault which is truncated on the west by the Simi fault, but continues eastward. The Marr fault corresponds roughly to Dibblee's (1992a) Simi fault. Hanson (1981) described the Marr fault as a reverse fault that bifurcates east of Llajas Canyon to become the east and southeast-trending Llajas and Ybarra faults. The Ybarra fault displaces Saugus Formation, whereas the Llajas fault is overlain by that Pleistocene unit. The Llajas fault is roughly the same as Dibblee's North branch. The Ybarra fault was not recognized at the surface by Dibblee. Dibblee's South branch approximates the Corredo fault of Hanson. Squires (1983) recognized only segments of the South branch, as the eastern extent of his Simi fault.

Hanson (1981) raised the possibility that the inclined older alluvial fan, occupied by Marr Ranch, was derived from Tapo Canyon, now about 2km to the west. However, he also questioned the likelihood of this much lateral offset as he observed no offsets of other drainages to the west. Left-lateral offset of as much as 2km is suggested by Dibblee's (1992a) map, if the Simi anticline is considered to be the same structure as the Rocky Peak anticline. About 1km of strike-slip separation of the Eocene Llajas Formation is suggested by this same map. However, either of these apparent separations may be artifacts of dip-slip displacement of inclined structures.

Consulting studies have exposed hanging-wall faults (localities **42** & **43**) and footwall faults (localities **47**, **50** & **51**), but the main trace has been rather elusive. At locality **51** a series of at least 8 trenches verified the presence south-verging thrusts previously inferred from aerial photo interpretation. A program of borings may have detected the main trace at localities **44-46** and trenches may have exposed a south-dipping element of the main trace at locality **50**. Faulted Quaternary deposits were observed at localities **42**, **43**, **47**, **49-51** and **53**; Quaternary faulting is inferred at localities **44-46**. Young (but undated) soils appear to be faulted at localities **42**, **50** and **51**.

One other intriguing observation has come to light, but its relationship to the Simi fault is uncertain. Neblett & Associates (1998a,b; locality **53**) have observed an east-northeast trending late-Quaternary fault, with a minimum length of about 400m, that lies less than 1.5km south of the Simi fault. The fault was observed during grading for development in the hills which project south of the Simi fault at the eastern end of Simi Valley. No other faults have been mapped in this area. The shallowly north-dipping thrust fault has about 16m dip-slip separation of the base of the Quaternary section with indications of at least three faulting events. The fault extends to, but not into, the base of the moderately to well-developed topsoil. Slickensides observed in trenches suggest that the movement may have been principally thrust.

<u>Aerial Photo Interpretation and Field Observations</u> (Figures 3a,b,c; lettered localities are indicated where locality descriptions might otherwise be ambiguous (see Table 2); aerial photos used are listed on p.15)

<u>Newbury Park and Moorpark quadrangles</u> (Figure 3a)

In the western third of the Newbury Park quadrangle the Simi fault is suggested by a linear drainage and side-hill benches at the western map boundary, but loses surface expression eastward. The Simi splay is indicated by a strong alignment of tonal and topographic features. The Santa Rosa fault is only generally suggested by a gradually steepening front, except at locality **a** where a somewhat more abrupt toe of slope was observed in the aerial photos. The tonal contrast which extends northeasterly from this locality, toward the Simi splay, may relate to gently southwest-dipping bedding observed at the end of Calle Dia (locality **b**). At the geomorphic transition from Pleasant Valley to Santa Rosa Valley there is a suggestion of left-lateral offset of one canyon (locality **c**) along the Simi fault, but such stream deflections are otherwise not discernible along this portion of the fault zone. The complex fault zone in this area was corroborated by this writer's observation of exploratory trenching (locality **18**, Figure 2a).

Within Santa Rosa Valley, the Simi fault is mostly expressed by discontinuous tonal and vegetation features. These features may indicate a fault in bedrock, but do not reflect recency. At locality **h**, exposures in a recently graded building pad show that volcanic rock may have intruded along the fault plane, with no subsequent shearing evident along the contact. The more prominent structure is the Santa Rosa fault, its location indicated by a relatively abrupt break in slope at the southern margin of the Las Posas Hills. Very steeply dipping Saugus Formation (N60°E, 60°-80°SE) at locality **d** further indicates the associated deformation in the western part of Santa Rosa Valley. The Santa Rosa fault trace is indicated to the east by the abrupt change in slope gradient, faceted spurs, sidehill benches and linear drainages. Additional thrust faults are suggested by two shorter alignments of slope breaks farther south, at the eastern end of the valley. Near the eastern edge of the Moorpark quadrangle a splay of the Santa Rosa fault was observed within an outcrop of diabase and basalt. Localized backthrusts of the Santa Rosa fault (**e** & **g**), observed in some trenches (locality **20**, Figure 2a), are also suggested by alignments of saddles and tonal lineaments.

The shorter fault strands (including the Kew Quarry fault) within the highly eroded southern slope of the Las Posas Hills, north of the Simi fault, are expressed as erosional features and tonal or vegetational lineaments in the bedrock. However, bedding is sub-parallel to the fault zone and could be responsible for many of the observed tonal and topographic lineaments. A possible graben is suggested by slightly sunken sections of three adjacent ridges (locality **f**). There is, however, very little expression of these faults within the remnants of an old, gentle landscape on the ridge top.

<u>Simi Valley West quadrangle</u> (Figure 3b)

The western half of the fault zone in the Simi Valley West quadrangle is locally very well defined by tonal and vegetation lineaments, as well as some north-facing scarps. A drainage course at locality **i** shows indications of elevation and incision north of the Simi fault. A series of three low ridges or knolls south of **i** (along the north margin of Tierra Rejada Valley), one of them with a natural depression behind it, is strongly suggestive of a thrust fault south of the identified main Simi fault. (This may be the eastward expression of the Santa Rosa fault). Among the more youthful features are some tonal contrasts across alluvium between ridges east of Highway 23. Fault features could not be clearly detected across the landslide complex northeast of Tierra Rejada Valley. Well-defined ridgetop troughs (locality **j**) are probably shaking-related ridgetop spreading features.

Arcuate lineaments, just west of where the Simi fault crosses Arroyo Simi, seem to be the result of shallow thrust faults, some of which have been corroborated in trenching (locality **36**, Figure 2b). A low linear knoll (south of locality **37**, Figure 2b), that appears to have risen up across the active drainage (and consequently eroded away on the east), may be related to these southerly thrust splays. This knoll is visible on older aerial photographs but has since been graded away.

A possible extension of the aforementioned knoll is suggested, across the arroyo, by weak north- and south-facing scarps. A linear drainage, the more northerly of two east of the arroyo, may extend the main fault alignment nearly to the railroad right-of-way. The remainder of the Simi fault, east of the arroyo, is expressed by the somewhat linear mountain front, but is less obvious in detail. Analysis of alluvial fans on the topographic base (Simi West quadrangle) and aerial photos reveals no apparent scarps or drainage offsets, although at locality **k** the fan margin may have been shifted eastward relative to its source. At several points along this front the slope base is relatively more abrupt. However, most of these slope-breaks might be due to resistant bedrock, lateral stream erosion or impingement of small fans emanating from minor canyons.

Simi Valley East quadrangle (Figure 3c)

The main expression of the Simi fault, as to the west, is the grossly linear mountain front. However, there are some suggestions on this quadrangle of recent displacement. At locality **m** an alluvial fan ends abruptly in either a scarp or sharp fold; the scarp, the eastern part of which is obscured by subsequent fan deposition, appears too large to be due to lateral erosion. At localities **l**, **n**, **o** and **p** there is a suggestion of left-lateral offset on the order of 30-60m. Localities $\mathbf{n_2}$, **o**, and $\mathbf{p_2}$ appear the most convincing, with offset channel margins apparent in the 1939 photography. Left-lateral offsets of drainages and ridges, of a similar magnitude, are also noted east of Marr Ranch. The seeming right-offset of Las Llajas Canyon and several smaller canyons, to the east, is puzzling, and may cast suspicion on interpretation of any of the apparent deflections east of Marr Ranch.

In addition to the expression of the main trace of the fault, there are indications of subsidiary faults across the gently sloping older fan surface at Marr Ranch, principally a subtle, slightly sinuous break-in-slope associated with tonal lineations. This latter feature has recently been trenched (locality **51**, Figure 2c) and the presence of faulting verified.

Discussion and Conclusions

Moorpark quadrangle and Newbury Park quadrangle

The Simi fault is a well-defined fault across both quadrangles, with a more youthful expression along the splay fault mapped between the Simi and Santa Rosa faults. The Santa Rosa fault is poorly expressed on the west but becomes quite well defined eastward. It appears that the combined zone of the Simi and Santa Rosa faults is spreading out westward and becoming less active at the surface, with no expression on the adjacent Camarillo quadrangle. Presumably, as the Simi and Santa Rosa faults diminish westward, strain is shifted to the active Springville and Camarillo faults. The Santa Rosa fault, blind in the western part of the map, becomes a more sharply expressed surface fault eastward into Santa Rosa Valley. The Simi fault appears to be most active (based on displaced soils at localities **8b**, **12**, and **18**, Figure 2a) where the Santa Rosa fault is still blind, and the Santa Rosa fault, where it surfaces eastward, becomes the more active surface strand, with numerous geomorphic indicators of displacement and displaced slopewash (locality **20**, Figure 2a) along the apparent backthrust.

In the eastern half of the Moorpark/Newbury Park quadrangles the Simi fault does not have any indication of recent movement, and in some cases, such as locality **h** (Figure 3a), appears inactive. There may be some strain partitioning, with a diminishing strike-slip component accommodated by some strands of the Simi fault. The flower structure interpreted at locality **18** (Figure 2a) supports the strike-slip interpretation and fits the apparent westward divergence of the structure from this point. Much of the compression in this part of the fault zone seems to be shifted southward to the Santa Rosa Valley fault (discussed in a later section).

Although the trace of the Santa Rosa fault, as identified here (after mapping by Weber and others, 1976), has not been explored by subsurface investigation it appears to be a justifiable interpretation based upon the strong geomorphic expression and the trench data supporting a backthrust (locality **20**). The topographic relief and apparent lack of lateral offsets suggest that the

Santa Rosa fault may be principally a reverse element of the fault zone.

With the exception of the possible graben at locality **f** (Figure 3a), the strands in the dissected terrain north of Santa Rosa Valley do not appear active. This is supported by the fact that they are not expressed within the more stable, old landscape (where fault geomorphology should be preserved), and appear only as expressions of erosion or lithologic contrasts in actively eroding terrain. The graben may be an expression of lateral spreading or similar shaking phenomena rather than faulting.

Simi Valley West quadrangle

At the southwestern corner of the Simi Valley West quadrangle the Simi and Santa Rosa faults appear to be coming together, much as the two strands of the Simi fault merge 10km to the west. The south dips recorded at locality **28** (Figure 2b) may indicate that the observed trace is complementary to the presumed north-dipping Santa Rosa fault, the two being different elements of a flower structure. Stratigraphic and paleontologic data (discussed above), if correctly identified, require a previously unrecognized fault (part of the Santa Rosa fault?), south of the observed trace of the Simi fault. This southern fault could extend northeasterly, perhaps to join the inferred thrust along the north margin of Tierra Rejada Valley. At Tierra Rejada Valley the thrust hypothesis is supported not only by the topographic features, but also by the suggestion of a backthrust at locality **31b** (Figure 2b). However, the western part of this inferred thrust has no expression suggestive of recency. Only where it bounds the north side of Tierra Rejada Valley does it gain some sharpness of expression. If a thrust is here, it would help explain the brecciated appearance of some of the exposed volcanic rocks. If these rocks are tectonically sheared they need not be a Quaternary-age, gravitationally displaced unit, as suggested by others.

The Simi fault continues eastward, across the quadrangle, as probably one main strand, with secondary faults splaying off to the northeast. Only one of these splays displays any geomorphic evidence of recency (at locality **33**, Figure 2b). Low-angle thrust faults are mapped south of the fault at locality **36** (Figure 2b) [and to the east at locality **51** (Figure 2c)]. The thrusts at locality **36** are expressed in what is probably a Holocene surface. It is unknown whether similar thrust faulting occurs at other localities, but the occurrence may be related to steps or bends in the fault alignment. At Arroyo Simi there is a notable right-step in the generally straight fault, and this would be expected to be a compressive zone along a fault with a left-lateral component of slip.

At the western end of Simi Valley, where the Arroyo Simi drains northwest across the Simi fault, it is apparent from both topography, site specific studies and water well data that the fault has repeatedly moved to impede drainage from the valley. This has resulted in a shallow bedrock sill north of the fault at the outlet of the valley, but over 150m of Quaternary and Holocene valley fill south of the fault (Yeats, 1983).

Latest surface displacement on the fault seems to be partially constrained by studies at Arroyo Simi (locality **37**) where faulting occurred less than about 7666±50 ybp, but before 1205±80 ybp (Hitchcock and others, 1997, 1998). East of the arroyo, at locality **38** (Figure 2b), latest faulting is either older than 4000 years, or else the trench failed to cross the fault. [Data farther east, at locality **44** (Figure 2c), suggest that the eastern section of the fault has not moved in at least 6500 years. This does not necessarily constrain activity to the west, however].

Simi Valley East quadrangle

The Simi fault continues across this quadrangle, grossly expressed by the linear mountain front, but lacking prominent offsets of the modern topography. From Dry Canyon, westward, alluvial fans are evident at the mouths of most canyons, as would be expected along a fault-bounded mountain front. However, to the east the major drainages (Tapo and Chivo canyons) appear to have incised their older fans, with more recent fan deposition occurring out from the mountain front. This shift in erosion/deposition could be either climatic or tectonically induced (due to southward tilting or another, perhaps diffuse, zone of uplift out from the front).

The lack of geomorphic expression of the fault across the inset fans of Dry Canyon and Tapo Canyon is not surprising as these are young fans (soils have A/C profiles per USDA, 1970). High rates of erosion to the north have probably masked much of the fault along the base of the hills. Nevertheless, recent activity is suggested by offset soil or colluvium west of Dry Canyon (locality **42**, Figure 2c), left-lateral deflections of several channels (localities **n**, **o**, and **p**, Figure 3c), subtle expression of thrust faulting at Marr Ranch, and faulted soils exposed at Marr Ranch (localities **50** and **51**, Figure 2c).

The extensive trenching at Marr Ranch has provided considerable evidence of low-angle footwall thrusting that may be typical of the entire fault or may occur at only some localities where the fault activity is either stepping over or splaying out. The latter explanation is also suggested by the previously mentioned southward shift in fan deposition in the eastern Simi Valley. The steeply south-dipping northern faults and generally shallow north-dipping south strands, mapped by others, resemble the "flower structure" commonly seen in transpressive fault zones. The deflected drainages, indicative of strike-slip displacement along the main fault, and thrusting southward suggest strain partitioning may be occurring in the Marr Ranch area.

Eastward from Marr Ranch the nature of the fault zone appears to change, as it veers to a more east-west and then southeast trend. The faults also notably lack geomorphic evidence of recent activity.

"SANTA ROSA VALLEY FAULT"

Summary of Available Data (Figure 2a; see Figure 1 for inferred fault location)

The proposed "Santa Rosa Valley fault" was informally named and recommended for zoning where it is well expressed on the Camarillo quadrangle (Treiman, 1997). This zone of faulting and associated folding extends eastward from the Calleguas Creek flood plain, about one half mile north of Camarillo High School (Camarillo quadrangle), and then along the north side of Pleasant Valley and the medial part of Santa Rosa Valley (on the Newbury Park quadrangle). This inferred structure has also been referred to as the "Santa Rosa Road fold/fault system" by Boales (1991). Part of the western half of this fault, within Pleasant Valley, was shown previously by Bailey (1951) and later compiled by Weber and others (1973 & 1976). (Pleasant Valley is separated from Santa Rosa Valley by a northward-projecting ridge of basalt that confines the flow of Conejo Creek). Weber and others (1976) mapped the westernmost part of the Santa Rosa Valley fault, as zoned on the Camarillo quadrangle; they also mapped about three kilometers of the inferred fault east of the basalt ridge, into Santa Rosa Valley. Pasta (1958) plotted part of this fault on his map, as well.

A study by Geolabs-Westlake Village (1990a; locality **1**) across the trend of this inferred fault, just west of the Newbury Park quadrangle, failed to find any evidence of surface faulting. Within the Newbury Park quadrangle, studies cited by Jakes (1979; locality **3**) identified a steeply dipping, east-west trending fault or fault zone along Santa Rosa Road, within Pleasant Valley and confirmed the anticlinal nature of that ridge. Also, in this vicinity, Thomas Blake (personal communication, 1997) observed a north-dipping fault at the bottom of a 22'-deep excavation, an observation confirmed by subsequent investigation (locality **2**, Figure 2a).

Localities **3**, **4** and **22** documented the anticlinal folding that accompanies this deformational front. Trenching at locality **5** exposed what appears to be tensional or normal faulting within the folded hanging wall of the main fault. Limited land development to the east, within Santa Rosa Valley, has not recognized or investigated the potential for fault rupture along this zone of folding and faulting.

Dibblee and Ehrenspeck (1993) mapped a short fault segment in the northern part of the Thousand Oaks quadrangle, near the intersection of Olsen Road and Highway 23. This fault segment, entirely within Conejo Volcanics with a suggestion of north side up, is somewhat on trend with the Santa Rosa Valley fault. Weber (1984) also mapped some minor bedrock faults in this area, however his faults appear to be only marginally related to those mapped by Dibblee and Ehrenspeck (1993).

Aerial Photo Interpretation and Field Observations (Figure 3a; lettered localities are indicated where locality descriptions might otherwise be ambiguous (see Table 2); aerial photos used are listed on p.15)

The most compelling evidence for this fault as a Holocene surface feature is a distinct scarp (east of Calleguas Creek on the Camarillo quadrangle) that is visible in older aerial photography (USDA, 1938, 1952; USGS, 1947). The scarp separates two relatively level, inferred Holocene, surfaces to the north and south. Where the fault projects along the base of a hillslope, an older north-south trending channel-cut projects north directly into the hillslope, suggesting 100'-150' of left-lateral displacement. This scarp was recommended for zoning as a surface fault by Treiman (1997), and included in an Alquist-Priolo Earthquake Fault Zone (California Division of Mines and Geology, 1998a). Almost equally convincing, for surface rupture, is a series of short arcuate scarps that have been mapped by this writer in Santa Rosa Valley, in the vicinity of Blanchard and Duval roads (localities **v** & **w**). At **w** a drainage has been incised into the uplift northeast of the fault.

The principal expression of this fault, on the Newbury Park quadrangle, is a distinct uplift of the valley floor, largely north of Santa Rosa Road. The uplift has forced the main east-west drainage to run close to the southern margin of the Santa Rosa Valley. North of Pleasant Valley the gentle gradient of the uplifted area is apparent on the topographic map, giving a clear impression that this was originally a single broad valley. In Santa Rosa Valley the uplifted area is either slightly more inclined or has been masked somewhat by alluvial fan deposition from the Las Posas Hills, but is nevertheless distinct from the valley floor to the south. The incised, and now largely abandoned drainage at locality **w** is clear evidence of this zone of uplift, as is the current incision of Arroyo Santa Rosa (near locality **y**).

The uplift area is marked on the south by a series of right-stepping east-northeast-trending ridges with relatively abrupt southern slopes. The toe of slope is somewhat gentle at the western end of the quadrangle (locality **q**) and between localities **t** and **u**, where the fault may not reach the surface, but is more distinct elsewhere. It is possible that the relatively abrupt toe of slope may have been accentuated by lateral erosion at localities such as **t**, **y** & **z**, but other features attest to the deformation as well. Locality **r** may be an old stream meander, now abandoned due to uplift and tilting. At locality **s** bedding dips gently north, north of the road, and immediately south of the road bedding dips about 70° south. Some of the highest scarp angles (**u** & **x**) are not in positions likely to have had much lateral erosion, although the high angle at **x** may be due to more resistant conglomeratic sandstone (Saugus Formation or older alluvium). At locality **z**, although lateral erosion is a possible explanation, the drainage is relatively broad and there is not much catchment upstream to produce a laterally erosive stream. Expression of the deformation zone is less well-defined to the east, as resistant volcanics and a more confined drainage render the topographic features ambiguous.

Backthrusts are suggested at several locations in Pleasant and Santa Rosa valleys. These inferred faults (marked **bt**) are suggested by aligned drainages, saddles and tonal lineaments north of linear ridges.

Discussion and Conclusions

Interpretation of older aerial photos and soil survey data (USDA, 1970) provides reasonable justification for the zoning already established on the Camarillo quadrangle (California Division of Mines and Geology, 1998a). Within the current study area, the distinct uplift of the floor of Pleasant Valley and Santa Rosa Valley demonstrates the presence of the fault zone, although the somewhat discontinuous surface expression suggests that the fault may be, locally, blind. I infer the right-stepping ridges to be the surface expression of young, *en echelon* folds, bounded by thrust faults on the south, and discontinuous backthrusts to the north. Very limited trenching (localities **3** and **5**, Figure 2a) has found scattered extensional faulting, probably associated with the folding, but has not found the main trace, except possibly at locality **2** (Figure 2a). However, the secondary faulting at locality **3** (Figure 2a), deformation at locality **s** (Figure 3a), and abrupt topographic expression at localities **t-z** (Figure 3a) argue strongly for a fault at or very near the surface at these localities.

Several backthrust segments are suggested by the topography, but have not been explored, except at locality **5** where recency could not be demonstrated. Geomorphic expression of the backthrusts is particularly fresh-looking where the main fault appears to have not yet surfaced, most prominently to the northwest of locality **u** (figure 3a). It may be inferred that the backthrusts remain active as long as the main fault is blind, but when the main thrust ruptures to the surface the backthrust becomes less active, or inactive. This situation is similar to that described by Whitney and Gath (1991) along the western Springville fault (see Figure 7). Some of the inferred topographic expression of the backthrusts may be merely due to alluvial fans impinging on the north side of the anticlinal ridges, with accompanying stream deflection along the back side of these ridges. This may be the case north of locality **t** (Figure 3a), and might have been so at locality **5** (Figure 2a) were it not that trenching confirmed faulting at that latter locality.

Locality **z** (Figure 3a) is supported as a fault scarp by soil survey data (USDA, 1970; see Figure 8) that shows the same clay soil (Cropley clay) above and below the scarp. The scarp area itself is mapped as Vina loam which is very similar to the clay loam parent material of the Cropley clay, suggesting that the sub-soil has been exposed in the scarp. The abandoned alluvial fan (Pico sandy loam) debouching from Arroyo Santa Rosa has partially obscured the western part of the scarp.

It is also worth noting the unusual drainage in the area of Tierra Rejada Valley. The valley is broad and flat with a relatively low gradient drainage. The deep incision of the Arroyo Santa

Rosa, as it exits the valley, suggests that it is an antecedent stream that has maintained its course as the hills beneath it have risen. This broader uplift could also be related to the Santa Rosa Valley fault.

SEISMICITY

Simila and Armand (1991) state that "the seismic activity along the [Simi] fault system is in response to a N-S compressive stress system," however, the zone "is characterized by a very low level of activity." A plot of seismicity from August 1983 to December 1993, included as Figure 9, shows very limited, low magnitude (<M4), epicenters near the Simi-Santa Rosa fault zone during this time interval. A more rigorous evaluation, considering hypocenter location and focal mechanisms would be necessary before attempting to draw any conclusions from the sparse data.

SLIP RATE

The Quaternary slip-rate for the Simi-Santa Rosa fault zone is poorly constrained. Previously reported slip-rate estimates are from the Springville fault (0.5-0.9mm/yr. reverse slip - Gonzales and Rockwell, 1991), Santa Rosa fault (0.09-0.14mm/yr. vertical separation at locality **12** - Blake, 1991) and from the Santa Rosa Valley fault (0.62-0.69mm/yr. vertical separation at locality **4** - Blake, 1991). The latter two estimates are extremely tenuous and based on uncertain offset and time-frames.

The slip-rate for the Springville fault (Gonzales and Rockwell, 1991) might be refined somewhat based on MRT ^{14}C dates obtained later (Leighton, 1993). In this later report it was stated that a dip-slip displacement of 0.6-1.1m has an average recurrence of about 900 years. This would suggest a slip-rate of 0.67-1.2 mm/yr. Uncertainties in the radiocarbon dating (discussed by Treiman, 1997) might halve this slip rate. The Springville fault slip-rate is from just one element of the fault zone (it does not include the Camarillo fault) and is from the extreme western end of the Simi-Santa Rosa fault zone. How it relates to slip-rate to the east is uncertain.

Whereas the above estimates refer to dip-slip rate, features observed to the east, in Simi Valley, demonstrate that there is also a component of left-lateral strike-slip displacement to be taken into account (locality **37**, Figure 2b, and localities **n**, **o** and **p**, Figure 3c). Data from locality **37** indicates that the strike-slip component may be at least 1.5 times the vertical. It is hoped that future studies at Arroyo Simi, proposed by this author and others, will better define the slip rate at this mid-point of the fault zone.

In the meantime, considering the uncertainties in slip-rate, slip geometry and slip distribution it might be more useful to estimate the general slip rate based on geomorphic expression of the fault zone. Slemmons and dePolo (1986) discuss the comparative geomorphic expression of faults within slip-rate categories separated by orders of magnitude. Based on the geomorphic expression of the Simi, Santa Rosa and Santa Rosa Valley faults, discussed in this report and delineated on Figures 3a,b and c, the fault zone seems to fall within their "Moderate Activity" category, "with moderate to well-developed geomorphic evidence of activity". This corresponds to a slip-rate between 0.1 and 1 mm/yr, a figure that falls within the realm of previous estimates summarized above. It also corresponds with a recurrence interval of 100 to 1000 years, a recurrence that is supported by studies on the Springville fault (Leighton, 1993) but not supported by some site-specific studies within the current study area (localities 37 & 44). Therefore, I would approximate the slip rate of the Simi-Santa Rosa fault zone to be between 1.0mm/yr and 0.5mm/yr, perhaps slightly lower toward its eastern end.

RECOMMENDATIONS

Moorpark quadrangle (Figure 10a, upper portion)

The portions of the Santa Rosa fault, as indicated on Figure 10a, are sufficiently active and well defined and are recommended for inclusion in a new Alquist-Priolo Earthquake Fault Zone. Fault location is based on Jakes (1979), Weber and others (1976), consultants investigations and aerial photo interpretation by this writer. Activity is based on geomorphology and faulted soil in Santa Rosa Valley and active faulting identified in Tierra Rejada Valley, to the east. The Simi fault, Kew Quarry and related faults on this quadrangle show neither geomorphic nor geologic evidence of recency and are not recommended for zoning at this time.

Newbury Park quadrangle (Figure 10a, lower portion)

The Simi fault and its splay, north of Pleasant Valley, and the Santa Rosa fault (and backthrust), within Santa Rosa Valley, are well defined. Based on evidence from the Tierra Rejada Valley to the east and geomorphic expression and trench data, these faults are deemed to be sufficiently active and should be zoned as indicated. Fault location is based on consulting reports and geomorphic expression interpreted by this writer, as well as mapping by Pasta (1958) and Weber and others (1976).

Portions of the Santa Rosa Valley fault and one backthrust, as indicated on Figure 10a are well defined and sufficiently active and should be included in an Alquist-Priolo Earthquake Fault Zone. Several other inferred and confirmed backthrusts do not show clear evidence of recent activity and should not be zoned at this time.

Unzoned segments of this fold and fault system appear to overlie an active, but buried fault; these segments present a risk of ground deformation and should be so identified in any future ZOD (see following section).

Simi Valley West quadrangle (Figure 10b)

The principal strand of the Simi fault as plotted on Figure 10b is active, well-defined over most of its length, and should be included in a new Alquist-Priolo Earthquake Fault Zone. Based on surface expression an inferred thrust north of Tierra Rejada Valley should also be included as should a secondary splay to the northeast. A zone of south-verging thrusts west of the Arroyo Simi is reasonably well-defined, probably active based on geomorphic expression and association with the active trace and should be included in the new zone. The fault locations are based on consultants reports, Hanson (1981), Jakes (1979) and aerial photo interpretation by this writer. Holocene activity is based on fault studies in Tierra Rejada Valley and at the Arroyo Simi.

Simi Valley East quadrangle (formerly Santa Susana quadrangle) (Figure 10c)

The principal strand of the Simi fault, as shown on Figure 10c, should be included within a new Alquist-Priolo Earthquake Fault Zone. The zone of south-verging thrusts at Marr Ranch should also be included as they are sufficiently active (based on offset soils) and well-defined (based on aerial photo lineaments and breaks in slope). The fault has not been evaluated ½-mile east of Chivo Canyon, and the possibility exists that active faulting extends east of the limits of the presently recommended Earthquake Fault Zone.

Report reviewed 10/8/98
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ZONES OF DEFORMATION

Portions of the Santa Rosa Valley fault zone are expressed at the surface only by folding (such as locality **q**, Figure 3a). Some of these fold zones are accompanied by possible backthrust zones (**bt**), perhaps resulting from intercalation backthrusting, as was proposed in the western Camarillo Hills (Whitney & Gath, 1991; Treiman, 1997; see Figure 7). In areas where the fault is deeply buried, primary surface faulting has not occurred and the propagation of future rupture to the surface may be unpredictable. Furthermore, the fold areas may be prone to minor, distributive normal faulting, such as that associated with locality **5** (Figure 2a). Although it may not be practical to avoid these uncertain ground ruptures and areas of tilting and folding, it may be practical to incorporate greater strength into foundation design in such areas. In order that such reenforcement may be considered, particularly for important or high-occupancy structures, limited Zones of Deformation might be recommended in the future. "Zone of Deformation" is an informal title, and there is no such zone officially designated by the State of California at this time.

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Fairchild Aerial Surveys -- flight C348 -- scale: 1"=1000' -- b/w
frames G14, K21 & K22 1928

NASA flight 04688 scale: 1"=1500' b/w
frames 459-465 & 512-520 1/21/94
flight 04689 scale: 1"=1500' b/w
frames 0092-0098 1/21/94

Pacific Western Aerial Surveys -- flight PW VEN -- scale: 1"=2000' -- color

6-85 to 6-94	10/10/88
6-120 to 6-133; 6-159 to 6-160	9/29/88
6-161 to 6-168	11/16/88

U.S. Department of Agriculture

1938 scale: 1"=1800'± b/w

AXI-19-6 to 19-16; 19-57 to 19-68; 19-73 to 19-86	5/9/38
AXI-43-4 to 43-9	6/4/38

1939 scale: 1"=1800' b/w

AXI-200-9 to 200-17	4/5/39
AXI-200-33 to 200-35; 200-57 to 200-66	4/7/39

1952-1954 scale: 1"=1800' b/w

AXI-1K-78 to 81	12/13/52
AXI-2K-34 to 36	12/22/52
AXI-2K-91 to 94	12/23/52
AXI-3K-11 to 13; 38 to 40; 66 to 70; 101 to 105; 192 to 193	1/3/53
AXI-9K-20 to 23	10/7/53
AXI-11K-178 to 181	1/14/54

U.S. Geological Survey -- flight USGS-EM -- scale: 1"=2000' -- b/w

1-60 to 1-62	8/15/47
1-87 to 1-89	8/15/47
5-52 to 5-69	8/20/47
7-03 to 7-09	8/24/47
5-111 to 5-122	8/20/47

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Table 1 (FER-244)
Site-Specific Data from Consultants' Studies and Other Cited Localities --- Simi-Santa Rosa Fault Zone
(Locations plotted on Figures 2a,b,c)

Loc	Consultant and date	Notes - C,N,M,W,E indicate Camarillo, Newbury Park, Moorpark, Simi Valley West and Simi Valley East quadrangles; SF, SR, SRV indicate Simi, Santa Rosa, and Santa Rosa Valley faults; Tsp - Eocene-Oligocene Sespe Formation; Tcv - Miocene Conejo Volcanics; TQs - Plio-Pleistocene Saugus Formation and its marine equivalent; *italicized notes are additional observations for this FER*
1	Geolabs-Westlake Village, 1990a	no surface fault; trench across fault projection shows TQs dipping 24°S in northern part of trench and shallowing to 4°S in southern part - (C,SRV)
2	Mountain Geology, 1998b	zone of six northwesterly-dipping (40°-74°) faults found at about 25'-30' below the surface; 2"-6" reverse separation of TQs, but not colluvium; study did not preclude additional strands - (N,SRV)
3	Geolabs-Westlake Village, 1978; Buena Engineers, 1988b; Gorian & Associates, 1989	30'-60' fault zone in TQs found in buttress cut along Santa Rosa Road; faults (EW strike, dips 80°S, 55°S & 51°N) considered to be secondary, hanging-wall structures; prominent ridge reflects anticline; smaller knob above road is also anticlinal; bedding overturned at southwest corner of property; post-tensioned slabs recommended to mitigate possible future folding - (N,SRV)
4	Buena Engineers, 1988a; Blake, 1991	documents anticlinal nature of ridge; ^{14}C dating shows younger alluvial deposits on south flank of ridge to be 23,000 years old - (N,SRV)
5	Earth Systems, 1997a, 1998	fault zone found in two trenches displaces TQs and probable terrace deposits (Qt) a minimum of 1m, but does not offset older alluvium overlying Qt; offsets show both normal and reverse separations; minor normal faulting (<15cm vertical separation) within TQs in southern part of property looks tensional, as above a fold - (N,SRV)
6	Geolabs-Westlake Village, 1990b; Staal, Gardner & Dunne, 1988	no evidence found, within Holocene deposits, for Simi fault or Santa Rosa fault; lack of faulting based on apparent continuity of alluvial units as defined in cone penetrometer test holes; Holocene age based on soil profile development - (C,SF/SR)
7	Dial Services, 1988	fault not found in long N-S trench; gently south-dipping "San Pedro Fm" (Quaternary) - (N,SF)
8	Buena Engineers, 1989 & 1990	a) Simi fault not found in long trench (T-8) mostly in TQs; fault may lie to north, in gap between two trenches, or may be concealed beneath older alluvium in northern end of trench; b) Simi splay (N66°E, 90°; N88°E, 61°N) found to displace hardpan and base of overlying soil (2'-5' vertical separation); opposite sense of separation in two trenches; c) additional south-dipping normal fault between Simi fault and splay did not affect soil and graded laterally into fold within TQs - (N,SF)

9	Tierra Tech, 1979a	Simi fault located in two trenches, reverse fault in TQs dips south at about 40°; fault zone is tens of feet wide, per log; no soil offsets observed - (N,SF)
10	Buena Engineers, 1981	Simi splay exposed in road cut; 2 vertical faults in TQs, N-side up, about 35' apart - (N,SF)
11	Pacific Materials, 1987	numerous north-dipping bedrock (TQs) faults on ridge top - (N,SF)
12	Buena Engineers, 1987; Boales, 1991	three south dipping faults and one low-angle north-dipping thrust; northern reverse fault dips 70°S, with 30' reverse displacement in TQs and offsets "B" soil horizon; central fault displaces TQs about 80', but does not affect soil; southern fault dips 40°-55°S with 45' normal displacement of TQs, offsets "B" soil horizon, and is interpreted to offset thrust fault. - (N,SF)
13	Westland, 1988a	no evidence of fault found in trench across mapped trace - (N,SR)
14	Westland, 1988b Swift, 1991	several south-dipping reverse faults in TQs observed in two trenches on ridgeline, believed to be part of a complex system of backthrusts; also observed normal faulting and north-dipping reverse faults; young, discontinuous soil not faulted - (N,SF)
15	Tierra Tech, 1979b	two strands mapped (Simi fault and Santa Rosa fault) based partly on Weber et al (1973); no specific fault planes were found, but significant zone of shearing and brecciation (60'-95' wide) of TQs and 5x to 8x thickening of soil was taken as evidence of fault zones; evidence considered stronger for young movement on the Simi fault - (N,SF/SR)
16	Blake & Larson, 1991b Blake, 1991	temporary slot cut exposes at least three faults/shear zones associated with Simi splay; considered to be a backthrust to Santa Rosa fault; faults are within TQs and were not observed to affect modern soil; authors report that trenches about ½-mile to the south did not find the inferred north-dipping Santa Rosa fault, implying that it is blind in this area; *northerly fault - N70°W, 60°SW; middle fault - E-W, dipping south; southerly fault zone, about 20m wide - N80°E, 90°* - (N,SF)
17	Geolabs-Westlake Village, 1992a	"zone of folding and faulting" mapped [map only reviewed, report not located] - (N,SF)
18	*personal observation, 1998* [unreleased consultant studies*]	*multi-strand fault and shear zone in TQs, resembling a flower structure (faults dip 25°N-45°S); high-angle faults in the middle of zone appear to offset colluvium; fault character suggests transpression* - (N,SF)
19	Pacific Materials Lab, 1988	Simi fault, located in trenches, separates Tcv from Tsp/QTs - (N,SF)

20	Tierra Tech, 1990; Pacific Materials Lab, 1988 Blake, 1991	fault zone in TQs located in trenches, principally south-dipping bedding plane faults (50°-68°, some shallower) that offset or pond slopewash deposits; variable separations: 30" reverse separation; 5' normal separation; ½"-1" gouge; Blake also reports in this vicinity a north-dipping reverse fault in two exposures - (N,SR)
21	Swift, 1994 *personal observation, 1993*	located Simi fault (N70°E, 70°-80°N) in TQs; *oblique slip likely, based on drag and mismatch of units; fault not traceable into weak soil* - (N,SF)
22	Ray, 1976	attitudes suggest gentle anticline, truncated on the south; ridge consists of siltstone and conglomeratic sandstone, tentatively identified as Saugus Formation, but may be older alluvium (personal communication, 1998) - (N,SRV)
23	Robert Stone & Assoc., 1969	fault located in mapping and trenches; no evidence for recency - (N&M,SF)
24	Gorian & Associates, 1977, 1979, & 1986	2 splays of Simi fault verified in trenches: northern fault- N85°W, 46N, southern zone of 8 faults within 55'-wide zone (dips 43°-78°N) thrusts Tsp over TQs; thin soil not faulted; Santa Rosa fault suggested by juxtaposition of Tcv against Miocene marine sediments - (M,SF/SR)
25	Gorian & Associates, 1977, 1979, 1988	"The fault zone is not a single feature, but consists here of three or more well defined fault traces each on the order of 2 to 4 feet wide. The traces may be identified in the field by sheared or slickensided surfaces and calichified zones exposed along the steep bluffs within the canyons in the northerly portion of the site. Attitudes observed on the slickensided shear zones of the fault traces strike generally east-west, and dip northward at angles of 65° to 90°."; faults were overlain by young, unfaulted topsoil- (M,SF)
26	[Gorian & Associates, field notes in company files, 1980]	mapping during grading shows ridge, south of Tierra Rejada Rd., to include Tcv, including vesicular basalt and volcanic agglomerate; basalt locally has baked contact with underlying sediments - (W)
27	Stone Geological Services, 1965	mapping at the northwestern corner of Tierra Rejada Valley shows "basalt flows and conglomerate" on hill, underlain by "tuffaceous sandstone"; two short northwest-dipping faults mapped within volcanic unit - (W,SR?)
28	Gorian & Associates, 1978	one principle south-dipping (37°-67°) fault exposed in two trenches, faulting Tcv over Tsp; fault did not displace undated soil or alluvium in one trench and in other trench main trace was not exposed; note: the fault trace shown on the map is based on pre-grading mapping - surface trace of fault shifted slightly south as a result of grading - (W,SF)
29	Earth Systems, 1995	major, steeply north-dipping fault with gouge, slickensides and sheared cobbles separates Tcv, on the south, from Tsp; steep south-dipping fault within Tsp; no offset of young alluvium - (W,SF)

30	Gorian & Associates, 1994b Shlemon & Simmons, 1995	main, high-angle fault zone identified across property, separating Tsp on the north from Tcv and possible TQs; up to 170'-wide zone of faults and shears with intense deformation focused in 15'-wide zone (trench D); at eastern property margin Tsp is thrust over inferred Holocene alluvium, with possible 3' offset of stone line (trench H); approximately 5' vertical separation of estimated 12,000-year old alluvium across one splay with deformation of overlying (younger) gravel (trench I); 2,000-3,000 year-old sediments not displaced; another major trace, separating Tsp from Tcv is inferred south of trench I - (W,SF)
31	Leighton and Associates, unpublished draft logs, 1996 *personal observation, 1996*	a) *multiple north-dipping thrusts (20°-50°) extend into soil, indicating probable Holocene activity*; b) possible backthrust (N72°E, 65°SE) of inferred southern thrust displaces volcanic breccia (Tcv or TQs), but doesn't appear to cut soil; colluvium-filled extensional faults on ridge south of pond die out at base of soil/colluvium - (W,SF, SR?)
32	Envicom, 1976 (loc.b - also Hanson, 1981)	a) concealed/inferred fault separates Tsp on the north from Tcv; 70'-wide subsidiary fault zone exposed within Tsp; b) roadcut for highway 23 revealed main north-dipping fault (65°) between Tsp (on north) and Tcv (on south); also secondary faults and folding in Tsp; [note that Dibblee (1992b), McClelland Engineers (1985) and Blake and Larson (1991b) show TQs, rather than Tcv, on the south side of the fault here] - (W,SF)
33	Gorian & Associates, 1990 McClelland Engineers, 1985	north-dipping (60°-86°) main fault found in several trenches; 5'+ shear zone; Tsp, on north, faulted against TQs; no offset of soil - (W,SF)
34	Blake, 1991	Blake reports exposures of several NE-trending antithetic faults (a), as well as possible main fault (f) where Tcv is faulted against TQs - (W,SF)
35	Gorian and Associates, 1981	steeply south-dipping fault zone (67°-88°) separates Tsp on north from Tcv; no offset of soil or older alluvium observed in trench - (W,SF)
36	*personal observation, 1998* [unreleased consultant studies*]	*young alluvial channel obscures contact relationship between steeply dipping Tsp and gently-dipping probable TQs in northern part of site, however, shears at base of channel, and minor faults (up to 4cm vertical separation) within channel are suggestive of an underlying fault; 7m south, main visible strand (N70°E, 65°-70°N; 25-30cm shear zone) separates TQs(?)on the north from massive older alluvium (Qoa); at least two shallowly north-dipping thrusts (9°-20° and perhaps flatter) farther south of main fault displace Qoa and stone line; additional thrust fault is interpreted in southern part of site by consultants, based on warping and fracturing of near-surface Qoa (shallow groundwater prevented deeper trench); $CaCO_3$ concentrated in orthogonal fractures in Bt soil horizon indicate tensional fracturing* - (W,SF)
37	Hitchcock et al, 1998 Hitchcock et al, 1997 *personal observation, 1997*	main strand located (N70-75°E, 90°) and dated Holocene; faulting occurred less than 7666±50 years ago, but before1205±80ybp; indeterminate offset with Tsp on the north faulted against at least 6m of late-Quaternary ponded sediments on the south; *mullions suggest left-oblique displacement; faulting extends up into undated alluvial terrace* - (W,SF)

38	Envicom, 1976	fault not located in trench (7'-15' deep) across mapped trace; unfaulted deposits are 4000 years old or younger, based on ^{14}C dating of carbonate nodules in buried paleosol; about 50% of trench did not even reach the dated paleosol - (W,SF)
39	CFS Engineering Geology, 1997	fault not identified in investigation and believed to be at least 50' south of proposed building footprint; *boring data show a possible 50-foot anomaly in depth to Tsp bedrock, suggesting that the Simi-Santa Rosa fault, or a significant splay, may lie under the southeastern part of site* - (W,SF)
40	Swift et al, 1991	north-dipping (46°-49°) fault thrusts TQs over late-Quaternary alluvium; *may warp late-Pleistocene/early-Holocene stone line* - (W,SF)
41	Holt, 1991	road cut on west side of Erringer Rd. exposes up-ended Tsp and several high-angle faults and shears that are sub-parallel to bedding; also two north-dipping normal faults displace probable Quaternary stream terrace - (W,SF)
42	Earth Systems, 1997b *& personal observation, 1997*	fault study delineated several hanging-wall faults that were judged by consultant to be inactive; largest strand (N72°E, 53°N) thrusts Tsp over older alluvium or TQs; *significant strand (N68°E, 32°N) displaces/deforms undated, but possibly Holocene, soil or colluvium; on-site structure, including late Pleistocene-Holocene (?) stone line, steepens southward toward inferred main trace* - (E,SF)
43	Mountain Geology, 1998a *& personal observation, 1998*	fault study identified several hanging-wall faults and, perhaps, part of main fault zone with offset of older alluvium and terrace deposits, but no offset of young residual soil or stream alluvium; thrust fault near southern limit of exploration dips northerly at 40° with indeterminate offset of older alluvium; 20° north-dipping fault juxtaposes different Sespe lithologies and shows apparent normal separation of older alluvium and terrace deposits; TQs or older alluvium is upended near the southern part of the trench; *main strand is inferred beneath southern part of trench or further south*; hanging wall faults further north include northwest- and southeast-dipping normal faults (45°-90°, up to 3m slip, maybe more) affecting older terrace deposits on Tsp - (E,SF)
44	[unreleased consultant studies, in progress, 1998]	fault studies for hospital identified abrupt drop-off of eroded top of Tsp/base of alluvium, based on boring transects; Tsp at ~6m on hanging wall and below 39m on footwall; no faulting or deformation observed in 2+m deep trench exposing massive to crudely bedded alluvium (6460±50ybp radiocarbon date obtained at 2m depth) [personal communication, G.Kasman/Law-Crandall, Inc.] - (E,SF)
45	Gorian, 1994a	borings show 30' or more difference in bedrock elevation (Tsp?), based on 2 borings about 170' apart; consultants infer fault is between borings - (E,SF)
46	Geolabs-Westlake Village, 1988 & 1992b	borings drilled on two sides of vegetation lineament; northwest boring hit sandstone bedrock (Tsp?) at 17' and southeast boring went 36.5' without reaching bedrock - (E,SF)

47	*personal observation, 1998* [unreleased consultants study*]	*trench encountered two shallowly north-dipping faults (N50°E, 30°-35°N; 8°-12°N) that thrust Tsp over older alluvium; older paleosol ("B"-horizon with stone line) dips south 12°-15° and is truncated at up-dip end by modern slope erosion; young "A" soil horizon is forming over eroded "B"; "B" may be slightly warped by faults but "A" appears unaffected and neither "A" nor "B" is faulted* - (E,SF)
48	Ryland, 1988	trench study, immediately east of reservoir, did not recognize faulting in sandstone (Tsp?); trenches crossed both inferred strands; *however, fault may be in gap between trenches or below trench depth; northern strand may have been expressed as a vertical clay seam identified in log of northern trench* - (E,SF)
49	Weber et al, 1976 (his photo 25)	reported fault exposure (fault dips 70°N), east side of Tapo Canyon Rd. (Eocene bedrock against probable late-Quaternary older alluvium or TQs) - (E,SF)
50	Buena, 1985	study located fault traces in several trenches; shallowly north-dipping fault (11°) appeared to enter soil zone, based on trench log and additional note in County geologist's files; south-dipping fault also observed - (E,SF)
51	*personal observation, 1998* [unreleased consultants study*]	*trenches for preliminary fault study documented several shallowly north-dipping thrusts (commonly 10°-15°) to the south of the mapped main trace; main trace was not investigated; most thrusts flatten out at base of modern soil, but some appear to displace base of young soil (presumed to be Holocene, based on lack of significant soil development); in some trenches soil development appears greater south of fault; south-dipping backthrusts appear in some trenches, and at eastern side of property the main southern thrust may be blind at about 10m depth with a south-dipping intercalation backthrust exposed in a trench; borings adjacent to eastern trenches showed greater than 28m vertical separation of eroded top of Eocene bedrock across main thrust fault; boring and trench data also show that the thrust fault steepens from near horizontal at 2m depth to 15-20° at 4m depth to 32° at 10m* - (E,SF)
52	Hart, et al, 1995	ground failure accompanying 1994 Northridge earthquake was suggestive of an extensional graben; may have been due to lateral spreading - (E,??)
53	Neblett, 1998a,b	north-dipping reverse fault (N50°E, 17°-34°N) was identified across site of residential development, prior to construction; slickensides plunge northerly; fault, which roughly follows bedding in Paleocene bedrock, thrusts bedrock over older alluvium and a buried paleosol; ~16m throw on base of Quaternary deposits, ~8m throw of base of paleosol (which is thinner on hanging wall), and younger gravel has about 1/3m throw; overlying soil (moderately to well-developed) on slightly dissected late-Pleistocene geomorphic surface is not affected; *data suggest at least three faulting events* - (E,??)

* Fault trench studies were performed by geologic consultants, but a report had not been released by the time of this Fault Evaluation Report. Fault characteristics were verified by personal observation of this author.

Table 2 (FER-244)
Photo and Field Observations, Simi-Santa Rosa Fault Zone (abbreviations as in Table 1)
(Locations plotted on Figures 3a,b,c)

Loc	Fault & quad	Observations
a	SR - N	-relatively abrupt toe of slope may indicate surfacing of Santa Rosa fault; possibly due to lateral erosion of stream
b	- N	-gently southwest-dipping bedding (15°) helps explain arcuate photo lineament as either bedding or unconformity
c	SF -N	-possible left-deflected drainage coincides with multi-strand fault zone - see also discussion of locality 18
d	SF/SR - N	-steep dips (60°-80°S) observed in road cut suggest deformation adjacent to fault
e	SF/SR - N	-topography suggestive of fault and backthrust
f	- M	-slightly depressed areas on three adjacent ridges are suggestive of a downdropped sliver, perhaps due to shaking or extensional normal faulting on the flank of a fold
g	SR - N	-aligned saddles follow secondary faulting above the inferred trace of the Santa Rosa fault
h	SF - M	-inspection of artificial cut, where one fault trace is mapped, shows intrusive volcanics with baked contact against Sespe Formation and no apparent shearing; suggests Simi fault may be inactive in this section
i	SF - W	-south-flowing drainage is incised north of fault, but not south, suggesting vertical displacement component
j	SF - W	-ridgeline troughs may be a result of faulting, but ridgetop spreading seems more likely
k	SF - W	-east margin of fan from unnamed canyon extends farther east than expected, possibly indicating left-lateral offset
l	SF - E	-possible older fan margin from unnamed canyon and distinct toe-of-slope suggest left-lateral offset
m	SF - E	-distinct escarpment across fan, west of small reservoir, suggests faulting or folding above a buried fault; eastern part of scarp obscured by subsequent fan deposition
n	SF - E	-two left-lateral offsets: 1) east margin of mouth of Dry Canyon/west margin of alluvial apron below faceted spur appear offset; 2) small south-draining channel is offset
o	SF - E	-left-lateral offset of eastern channel margin at mouth of Tapo Canyon

p	SF - E	-two left-lateral offsets: 1) deflected dry channel; 2) eastern channel margin of unnamed canyon is offset
q	SRV - N	-toe of slope in this area lacks sharpness, suggesting fault is locally blind, between distinct scarp on Camarillo quadrangle (to the west) and more abrupt slope to the east; linear drainage to the north suggest backthrust (bt)
r	SRV - N	-unusual topography suggests that a meander of Conejo Creek once occupied this hollow, and subsequent uplift and tilting has caused abandonment of this section of the drainage
s	SRV - N	-cut-slope adjacent to water district offices exposes gently north-dipping (~10°) sandstone; 1998 storm erosion exposed steeply inclined bedding immediately south of road (~N65°E, 70°SE)
t	SRV - N	-prominent ridge with abrupt southern margin; appears to be tectonic, but lateral erosion or floodplain deposition may have accentuated the toe of slope
u	SRV - N	-steepest scarp (20°) does not appear to be in a position where it may have been accentuated by erosion
v	SRV - N	-set of distinct short arcuate scarps suggests thrust fault is at surface
w	SRV - N	-incised drainage is antecedent to uplift along fault
x	SRV - N	-break in slope at mid-point may be due to second fault, or lithologic break
y	SRV - N	-steep slope may be continuation of scarp to the west, or may be erosional
z	SRV - N	-gentle 3-3.5m slope may reflect buried fault; drainage seems inadequate to cut bank

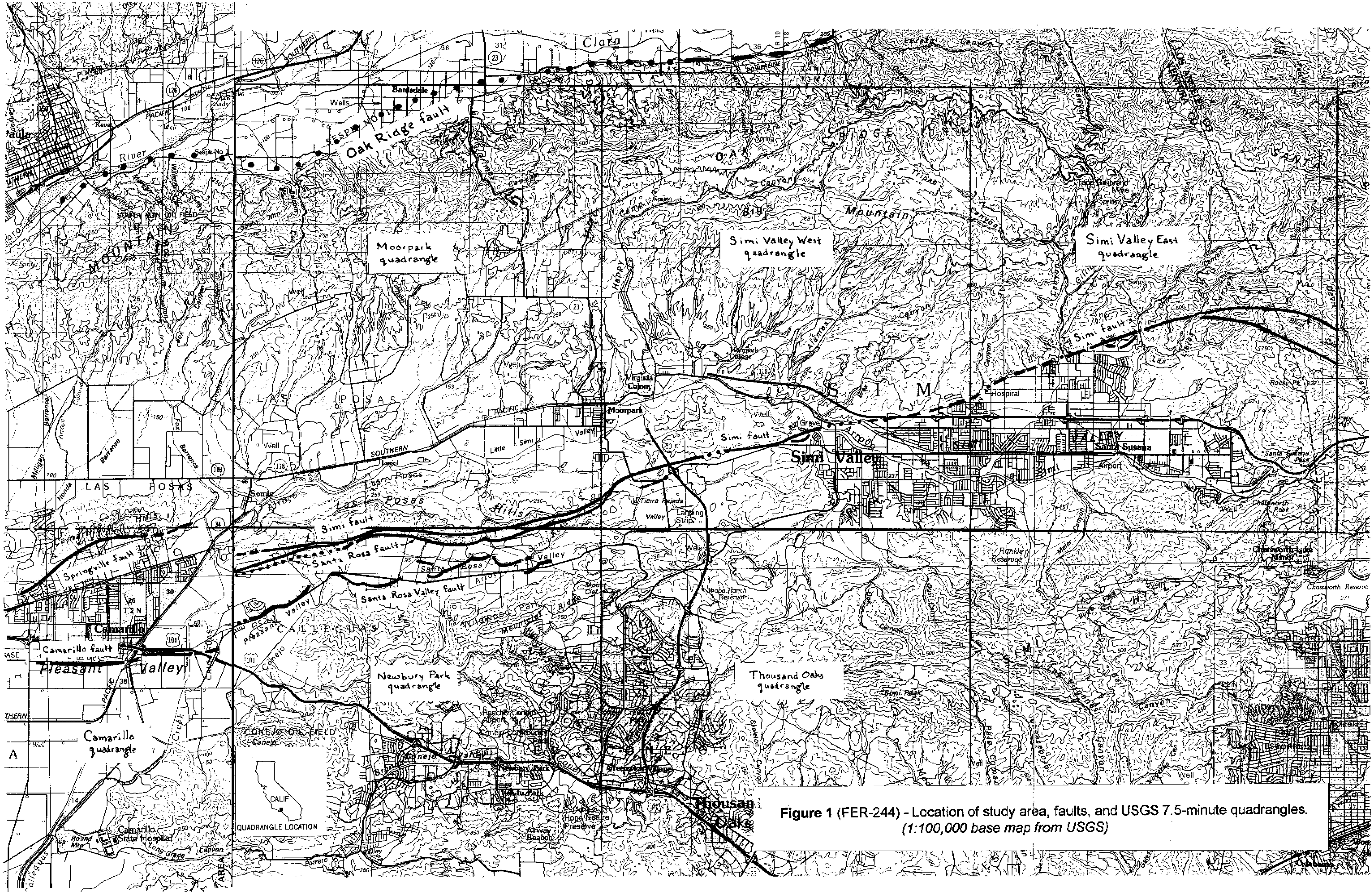

Figure 1 (FER-244) - Location of study area, faults, and USGS 7.5-minute quadrangles.
(1:100,000 base map from USGS)

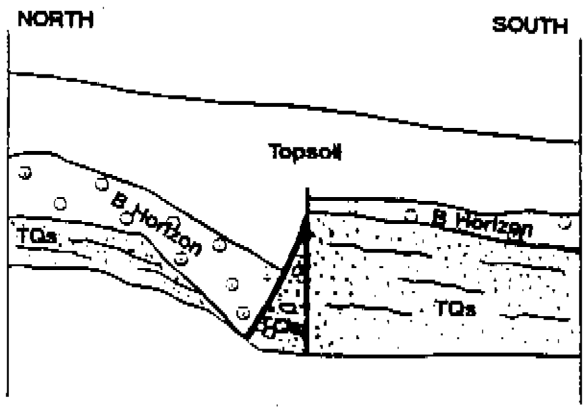

FIGURE A. Log of a portion of Trench No. 1, Fitzgerald Property. Splay fault offsets Saugus Fm. and overlying caliche-enriched B horizon.

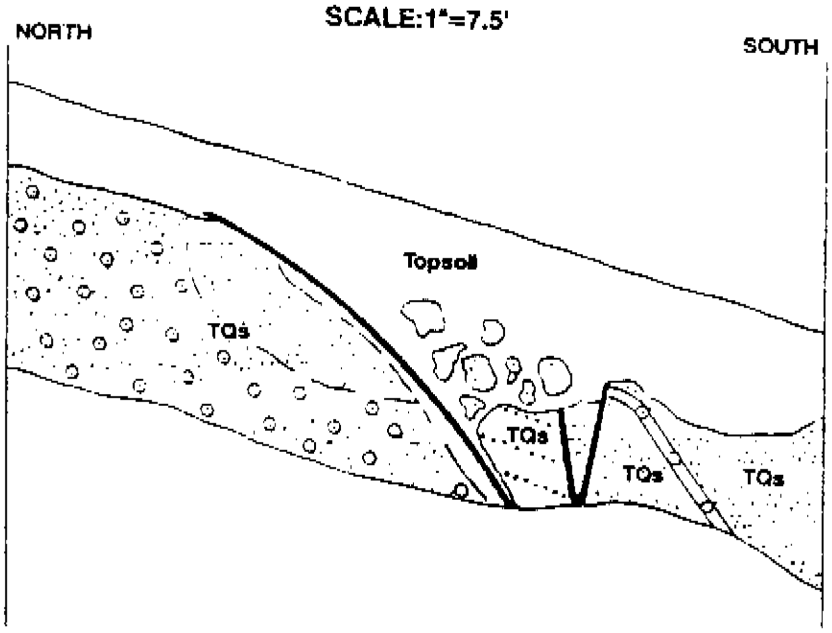

FIGURE B. Log of a portion of Trench No. 4, Tract 4298 (Rancho Barasso). Fault offsets Saugus Fm. Bedding north of fault obscured, but dip is slightly shallower than dip of fault.

Figure 4 (FER-244) - A) Portion of consultant's trench log at locality **8b** showing displaced topsoil; B) Portion of consultant's trench log at locality **12**, showing southern splay of Simi fault extending along soil/bedrock contact, and offsetting base of soil. (Figures from Boales, 1991)

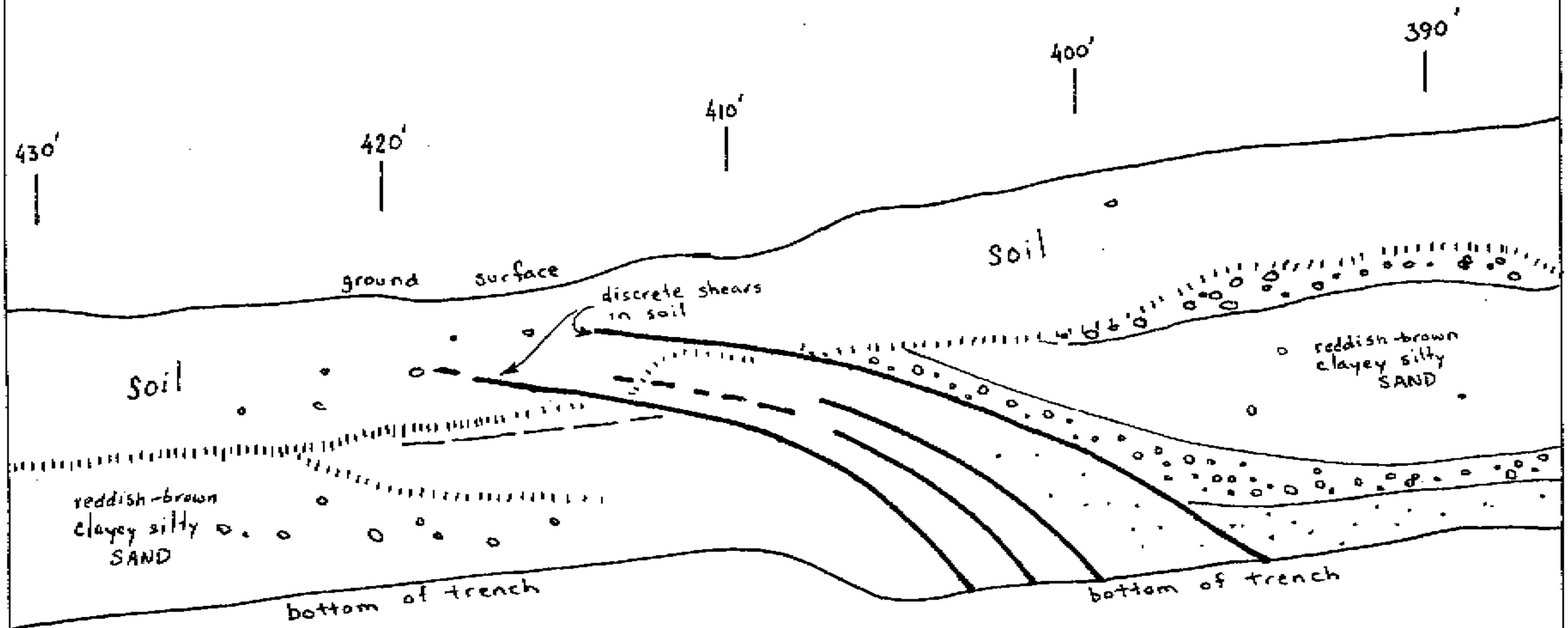

Figure 5 (FER-244) - Sketch log, after Leighton (1996) of a portion of the west wall of trench LT-1 (locality **31a**), showing shears extending up into soil. Fault attitudes - N33°E, 50°NW near trench bottom; N27°-35°E, 20°-22°NW in soil. Slickensides trend downdip. Scale: 1"=5' (logged at 1"=10').

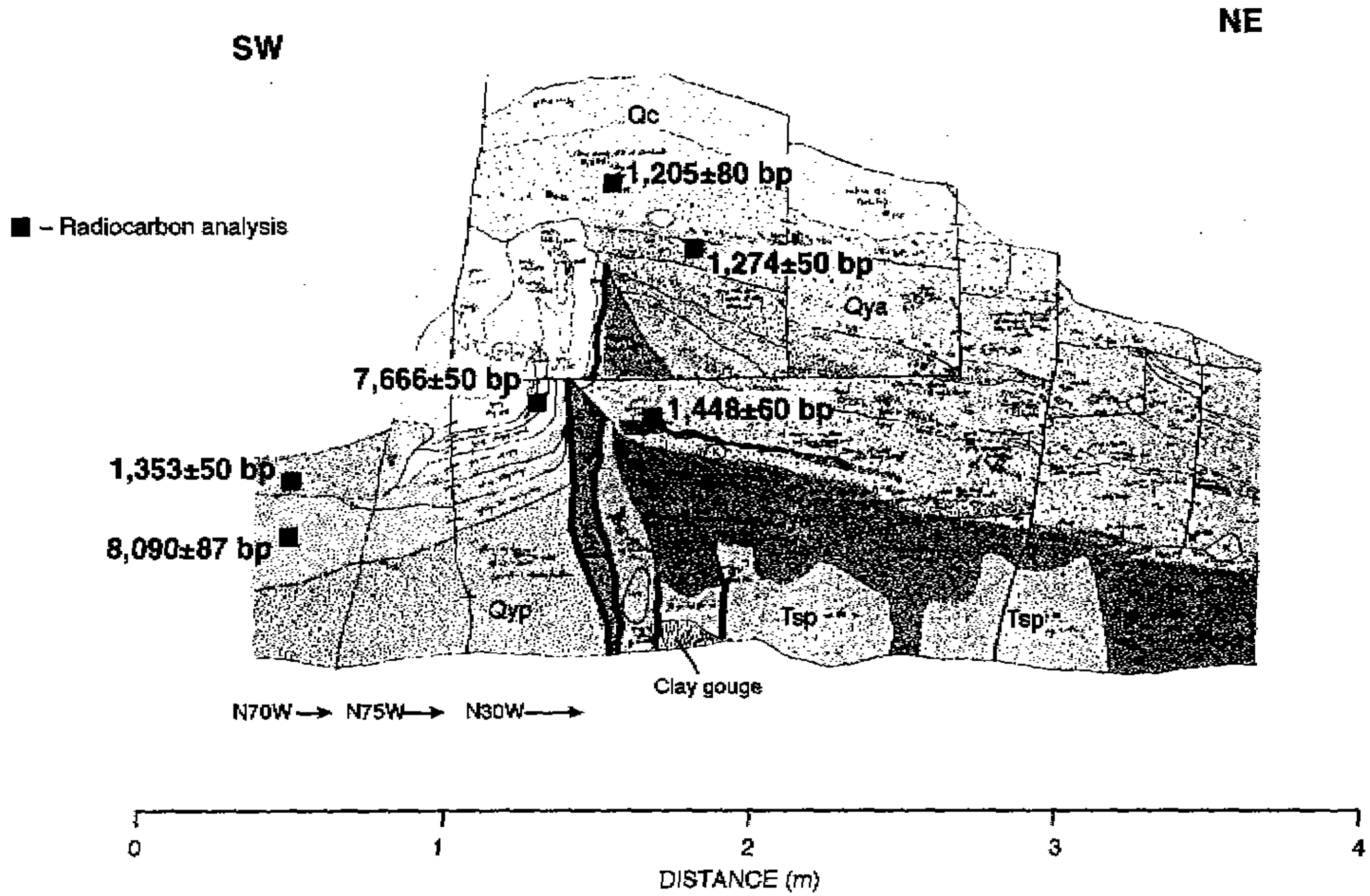

Figure 6 (FER-244) - Log of west bank of Arroyo Simi (locality **37**) showing deformation and offset of Holocene deposits. (from Hitchcock and others, 1997)

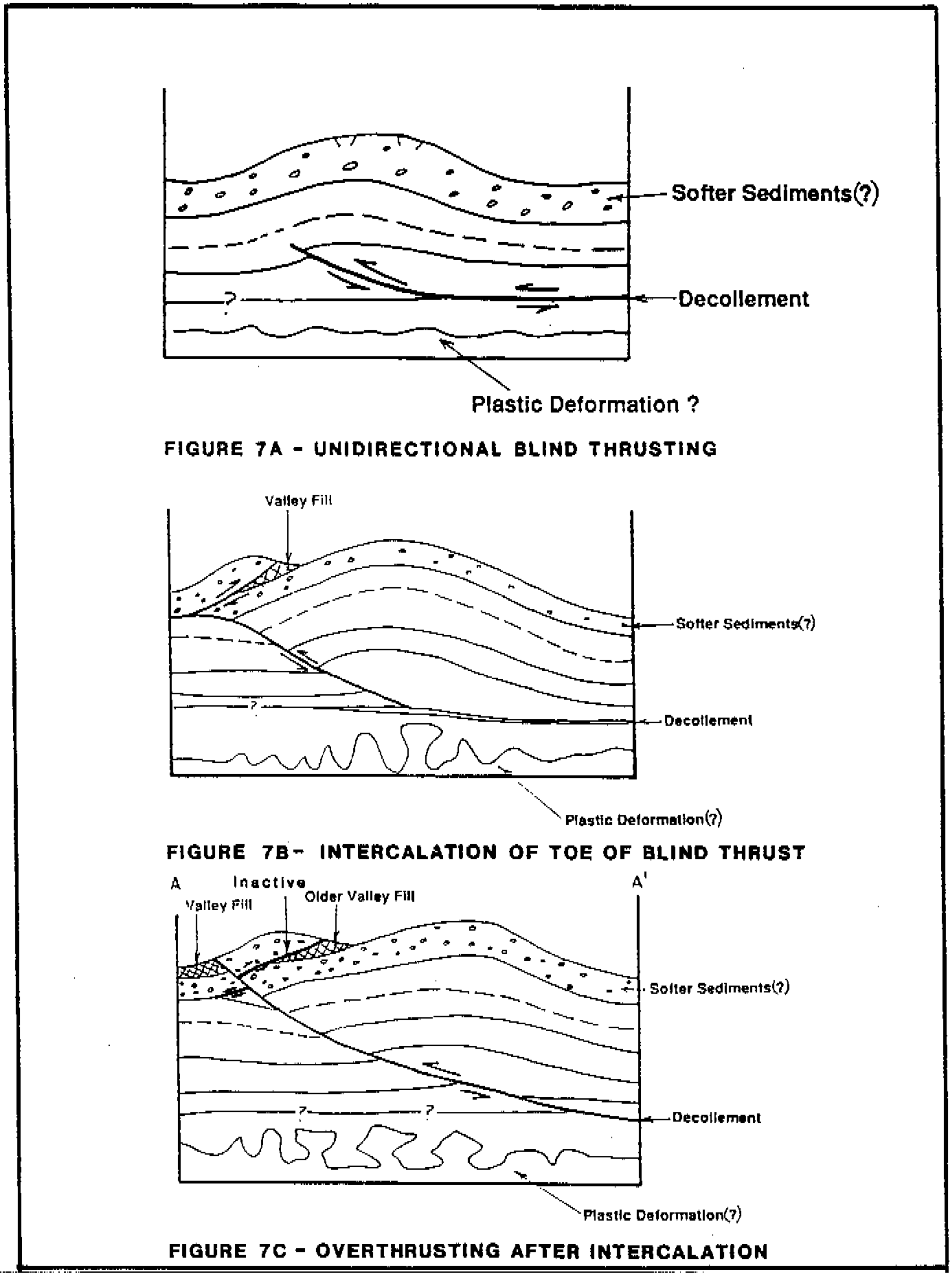

Figure 7 (FER-244) - Diagram illustrating the progression of an intercalation backthrust. Illustration (from Whitney and Gath, 1991) is for an area in the western Camarillo Hills, but it is believed applicable also to portions of the Santa Rosa Valley fault.

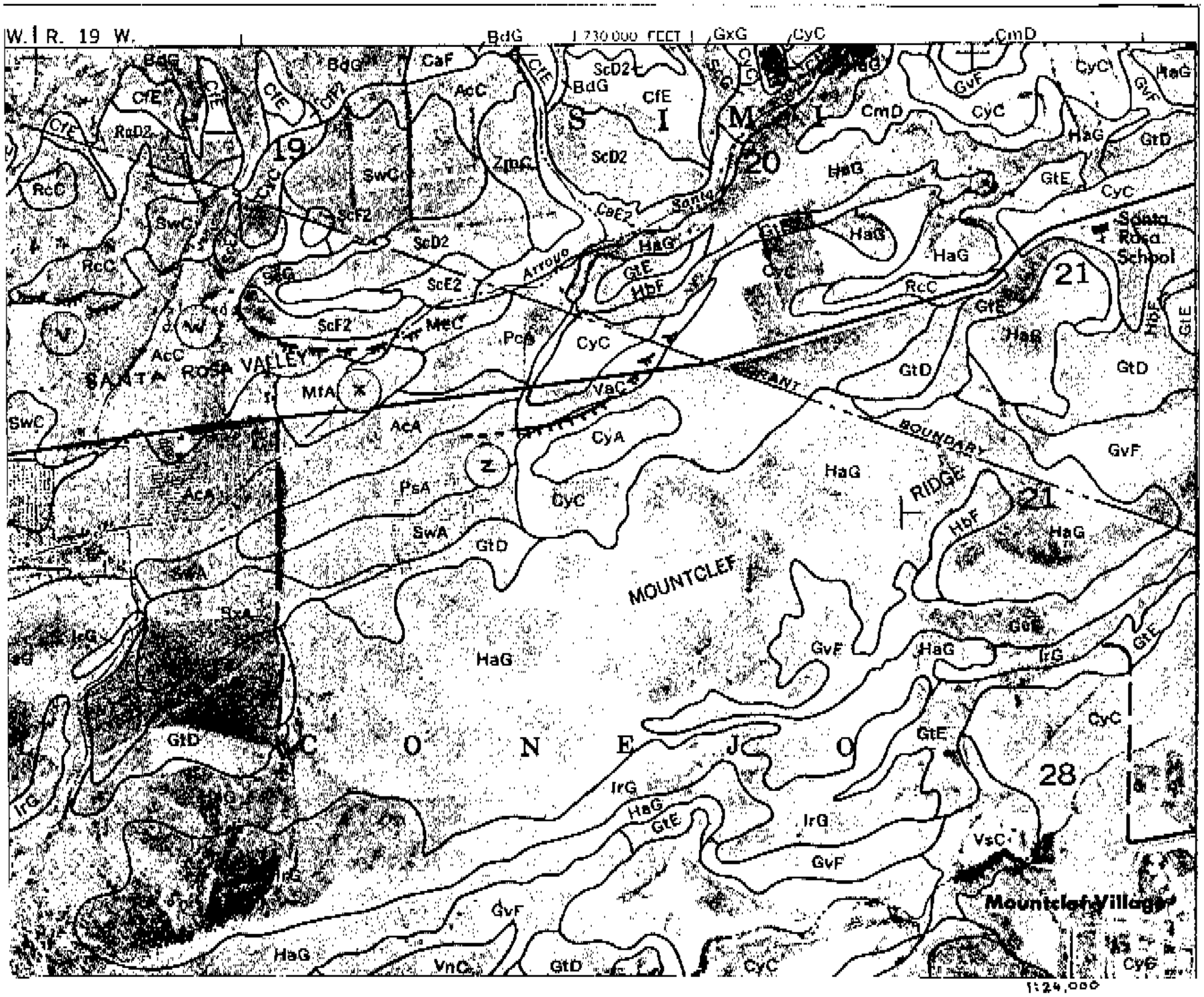

Figure 8 (FER-244) - Detail from Ventura area soil survey (USDA, 1970 - map sheet no.40). Cropley clay (CyC) in center of map is on elevated floodplain above scarp, and on modern floodplain to the south. Vina loam, surrounding CyC, appears as if it might be the Cropley subsoil exposed by faulting. Incised drainage also leaves Cropley clay elevated above fault.

AcA, AcC	—	Anacapa sandy loam - grayish-brown alluvial fan soil; A/C profile (A -35")
CyA, CyC	—	Cropley clay - dark gray alluvial plain soil; A/C profile developed on grayish brown silt loam and silty clay loam with 5-25% gravel (A -22")
MeC	—	Metz loamy sand - light brown alluvial plain or fan soil; A/C profile (A -7")
MfA		Metz loamy sand, loamy substratum - stratified below 40"
PcA	—	Pico sandy loam - grayish brown alluvial fan soil; A/C profile (A -14")
PsA		Pico loam, sandy substratum -surface loam with gravelly sand layer below
ScD2,E2,F2 ScG	—	San Benito clay loam - grayish brown upland soil; various steep slope gradients - A/C profile (A -25")
SwA, Swc	—	Sorrento loam - grayish brown alluvial fan and plain soil; A/C profile (A -19")
VaC	—	Vina loam - grayish brown loam to fine sandy loam with 5-10% gravel; alluvial plain soil; A/C profile (A -18")
Z		Locality from Table 2